AD NUMBER

AD480979

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; APR 1966. Other requests shall be referred to U.S. Army Electronics Command, Fort Monmouth, NJ.

AUTHORITY

USAEC ltr, 16 Jun 1971

AD

AD 480979

TECHNICAL REPORT ECOM-01320-3

QUANTUM MULTIPLIERS AND MIXERS

THIRD QUARTERLY PROGRESS REPORT

By

V. E. Derr and G. W. Bechtold

APRIL 1966

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commanding General, U.S. Army Electronics Command, Fort Monmouth, New Jersey, AMSEL-KL-SM.

ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

CONTRACT DA-28-043-AMC-01320 (E)

MARTIN-MARIETTA CORPORATION

Orlando, Florida

OR 8101

Disclaimer

Technical Report ECOM 01320 April 1966

QUANTUM MULTIPLIERS AND MIXERS

Third Quarterly Progress Report

1 November 1965 to 31 January 1966

Report No. 3

Contract No. DA-28-043-AMC-01320(E)

DA Project No. IP6-22001-A-05803

Prepared By

V. E. Derr and G. W. Bechtold

Martin Marietta Corporation

Orlando, Florida

(OR 8101)

For

U.S. Army Electronics Command, Fort Monmouth, N. J.

CONTENTS

Purpose vii

Abstract ix

Conferences and Publications xi

I. Introduction 1

II. Technical Discussion 3

A. Resonators 3
B. Beam Splitting 5
C. Gas Selection 11

III. Details of Experimental Design and Construction 13

IV. Experimental Effort During Third Quarter 15

V. Conclusion 23

VI. Program for Next Quarter 25

VII. Key Personnel 27

Appendix - Methylene Chloride Rigid Rotor Transition Frequencies . . 29

References 35

ILLUSTRATIONS

1 Interferometer Power Conversion Efficiency versus Resonator Geometry 9

2 Beam Splitter Double Interferometer 10

3 Cavity Coupling Setup 16

4 Magnetron - Cavity Lock Circuit 17

5 Test for Transmission of Third Harmonic in Interferometer Cavity. 18

6 Semiconfocal Interferometer with Tungsten Wire Perturbation . . . 20

7 Measurement of Cavity Field Distribution. 21

8 Setup for Measurement of Parallel Plate Interferometers 22

PURPOSE

Experimental and theoretical analysis will be conducted to determine power conversion efficiencies for harmonic generation due to nonlinear quantum susceptibilities. Analysis of partly resonant two-level schemes will be conducted, but the emphasis will be on the investigation of resonant harmonic generation within gaseous media where two levels are in resonance with the harmonic output and intermediate levels can be used to reduce pump power requirements for operation with optimum efficiency. Of primary importance in the experimental phase of work is the development of suitable resonant structures to support the multiple quantum system.

ABSTRACT

Various resonant structures that may be used in harmonic generation and frequency mixing experiments are discussed. The important parameters considered are simultaneous double resonance, filling factor, and resonator losses. The discussion compares the relative merits of various resonators.

The semiconfocal interferometer has been employed in partly resonant gas experiments using methyl fluoride. Crossed parallel plate interferometers have been designed for use in third harmonic generation in nitrosyl fluoride. Problems related to the use of the interferometers in multiple quantum experiments are discussed. Beam splitting techniques to improve the filling factor are also discussed.

The use of asymmetric top molecules in multiple quantum experiments is complicated by the corrosive properties of these gases. This problem is reviewed.

The experimental phase of the work was concerned with experiments to optimize the resonator structure for the partly resonant experiments and with an evaluation of the components to be used in the totally resonant work. This progress is discussed.

The energy levels of methylene chloride have been completed. These are given in the Appendix. Work on multiple quantum effects in solids was held in abeyance to allow for the revision of test equipment to incorporate a superconducting magnet in the test setup. Work on multiple quantum effects in solids will continue in the next quarter.

CONFERENCES AND PUBLICATIONS

Dr. V. E. Derr and J. J. Gallagher of the Martin-Orlando Physical Sciences Research Laboratory conferred with Dr. Harro Andresen, Contract Monitor, in New York City on 27 January 1966.

I. INTRODUCTION

Multiple quantum effects have been predicted since the introduction of quantum mechanics (Reference 1) and have manifested themselves in many ways. For example, such phenomena have been associated with Raman processes (References 2 through 8), molecular beam transitions (References 9 through 17) and optically pumped schemes (References 18 through 26). More recently, multiple quantum transitions have been observed in the microwave region and the feasibility of frequency conversion due to nonlinear quantum susceptibilities experimentally demonstrated (References 27 through 30).

The interesting possibility of producing millimeter and submillimeter radiation from such schemes has led to the consideration of partly resonant (Reference 31) and resonant (References 32 and 33) techniques. From an analysis of the power conversion efficiencies of the two methods, the resonant frequency mixing scheme shows the greater promise for frequency conversion devices in the millimeter region, although it requires more careful selection of materials.

In this report, a theoretical analysis of certain problems in resonators is given, the gas handling problem discussed, and the experimental work during the quarter reviewed.

II. TECHNICAL DISCUSSION

A. RESONATORS

The choice of an optimum interaction structure for multiple quantum frequency mixing experiments is an important consideration. Possible future use of the multiple quantum technique for frequency multiplication and mixing in the millimeter and submillimeter regions ultimately depends on the power conversion efficiencies that can be obtained. One of the major objectives of this program is to investigate various resonators to determine the optimum configuration. To date, experiments have been performed in re-entrant cavities by Fontana, Pantell, and Smith (Reference 27) in waveguide structures by Coleman and Akitt (Reference 34) and in a coaxial resonator by Scalapino, Vasiliadis, and Wilson (Reference 35). Although all of these experiments added to the state-of-the-art, none of the interaction structures appears to be well suited for use at higher frequencies. The important criteria of the resonator are:

1. Simultaneous double resonance at the fundamental frequency and the harmonic frequency or, preferably, flexible, independent tuning;

2. High filling factor and high-effective Q at both frequencies;

3. Large interaction volume, ease of coupling, and mode discrimination.

In the case of the re-entrant cavity, Fontana (et al) obtained the simultaneous double resonance by varying the height of the cavity and the length of the post. Since the field configuration in the re-entrant cavity was unknown, the filling factor was estimated to be 0.1. It is known that the E-field is large in the region between the end of the post and the cavity wall, and it is usually assumed that the generation occurs in this volume. This type of cavity may be useful in the frequency range below 35 GHz, but cavity losses limit its application at higher frequencies. The coaxial resonator has the advantage of known field configuration, but is also limited to use at frequencies below 35 GHz since the losses of the center conductor increase rapidly with frequency.

The rectangular cavity has the advantage of allowing the simultaneous double resonance with the proper phase relationship of the fundamental and third harmonic electric field to obtain a resonably high filling factor. An example of an appropriate mode would be the TE_{10} fundamental mode and the TE_{30} harmonic mode. The rectangular resonator has higher losses than a circular resonator operated in the TE_{01} mode. Also, the wall losses in the rectangular resonator increase rapidly with frequency, limiting its use to the lower frequency range.

Of all the conventional microwave cavities, the cylindrical cavity operated as a multimode cavity in the TE_{01} mode shows the most promise. The losses of this cavity are of the same order as the losses in the semiconfocal interferometer. Diffraction losses of the semiconfocal Fabry-Perot interferometer 61 cm in length and 12 cm in diameter total 2.17×10^{-4} db. The analogous wall loss of a cylindrical copper cavity of the same dimensions supporting the TE_{01} low loss mode is 7.68×10^{-4} db. The semiconfocal interferometer offers the advantages of ease of alignment and low loss in the frequency range from 50 GHz to 300 GHz. One disadvantage of this resonator is the problem of obtaining simultaneous double resonance in a two-mirror system. We have been able to obtain the simultaneous double resonance by introducing a small electric field perturbation. Since the field distribution in the interferometer is given by complicated Gaussian-Harmite polynominals, calculation of the field distribution with the perturbation would be prohibitively complicated. In the experimental section of the report, a technique is described to measure the relative field distribution in the cavity using a method that is simple and sufficiently accurate. Preliminary tests indicate that the same mode exists in the cavity, but the field distribution is slightly altered. The filling factor for the semiconfocal interferometer, calculated on the basis of a plane wave field distribution approximation, was found to be 0.05.

Another promising resonant structure is the parallel plate interferometer to which the coupling of power is accomplished by horn-and-lens feed through a coupling hole pattern in the interferometer plates. This is in contrast to the semiconfocal interferometer, where a waveguide-iris feed is applied to the center of the mirrors. Since the coupling hole size is calculated by matching the hole susceptance to the plate susceptance, it is a function of frequency. For this reason, it is difficult to employ a single pair of interferometer plates as a doubly resonant interferometer with the harmonic frequency an odd harmonic of the fundamental frequency. The use of a double interferometer to eliminate these coupling problems was discussed in the previous quarterly report (Number 2). The double interferometer allows ease of coupling, since the individual mirrors can be fabricated for one frequency only and the interferometers can be separately tuned to obtain the simultaneous resonance. A major problem with the crossed interferometer is in obtaining a sufficiently high filling factor. The filling factor may be computed from the following integral which was analyzed in the last report:

$$\iiint \sin^3 Kz \sin \left[3 Kz \cos \phi + 3 Ky \sin \phi\right] E^3 \text{(fund)}\, E\, \text{(harm)}\, dx\, dy\, dz$$

where:

K = wave number of the fundamental frequency
E (fund) = fundamental electric field
E (harm) = third harmonic electric field.

The angle ϕ is the angle of intersection of the cylindrical axes of the two interferometers. The filling factor has been calculated for several different intersecting angles between the axis of the interferometers. The ratio of the filling factor at 30 degrees and 90 degrees relative to the filling factor at 0 degrees is 3 percent and 0.5 percent, respectively. Since the filling factor and volume both increase as the intersection angle decreases, first experiments and volume both increase as the intersection angle decreases; first experiments will be conducted at an angle of 15 degrees. However, the use of this small angle presents other problems such as difficulty in physically positioning the mirrors so that the mirrors of one interferometer are not in the resonant path of the other interferometer. Because of these difficulties with the crossed interferometers, other techniques are under consideration to obtain parallel directed waves. One of these techniques is called beam splitting.

B. BEAM SPLITTING

One of the fundamental difficulties in the creation of usable multiple quantum harmonic generation devices is obtaining a sufficiently high filling factor while maintaining the power density and large volume necessary for efficient power generation at the harmonic. The following simplified expression for the third harmonic generation in the two-level case shows the parameters that must be optimized:

$$P_{3\omega} \approx \frac{\left(\frac{\mu}{h}\right)^4 \cdot \frac{f_2^{\,2}}{\alpha} E_1^{\,6} V}{128\pi\Omega^3}$$

where:

α = loss factor, $\alpha = Q_s \cdot f_1$

μ = dipole moment

Q_s = sample Q

E_1 = electric field due to first harmonic pump

V = volume of resonator

Ω = transition frequency of molecule

f_2 = filling factor of nonlinear third harmonic polarization

f_1 = filling factor of linear response (absorption) at third harmonic.

The factors f_2, f_1, E_1, and V are important in the design of a resonant structure. The large exponent of E_1 indicates that it is very important to have a large power density in the resonator, so that the choice of volume, configuration, and coupling should optimize this factor, but without penalizing the filling factor f_2. Another consideration is that the resonances at the fundamental and the third harmonic must both occur at the same setting of the tuning device in the resonator; otherwise, a serious loss of power will occur. The loss will result either because of low E_1 field or from having the output waveguide poorly matched to the third harmonic power.

In the expression for $P_{3\omega}$, it is useful to evaluate the role of $E_1^{\,6}$ in terms of the Q factor and the volume of the resonator. The losses from a resonator can be given by $P_L = \omega W/Q$, where ω is the resonant frequency, W the total stored energy, and Q includes losses of all kinds: diffraction, coupling, and reflection. In the steady state, the losses are compensated by the power input and hence the power into the resonator, i.e., the fraction of power not reflected at the coupling holes, must be equal to the power lost. Thus,

$$P_L = P_{in} = \frac{\omega W}{Q} .$$

Therefore,

$$\frac{W}{V} \alpha \frac{PQ}{\omega V}$$

where V is the volume of the resonator and P is the power moving down the waveguide toward the resonator.

In the foregoing, W/V is the energy density and is proportional to $E_1^{\,2}$. $E_1^{\,6}$ can then be eliminated from the expression for $P_{3\omega}$, obtaining

$$P_{3\omega} \propto \frac{P^3 Q^3}{\omega^3 V^3} \times V = \frac{P^3 Q^3}{\omega^3 V^2}$$

where uninteresting factors have been omitted. Thus, for fixed frequency and input power, we must make Q^3/V^2 as large as possible. It is clear that a gain in power output will be achieved by obtaining the maximum Q in the smallest possible volume. This point is considered below for a particular resonator.

Many resonator designs have been considered, but the major discussion here will concern the flat plate and the semi-confocal Fabry-Perot interferometers. The flat plate interferometer has the required ease of double resonance operation, the filling factor is potentially large, and the Q high. The difficulty of alignment compared to the confocal case is a problem. Further difficulties may arise when independence of tuning of the fundamental and the third harmonic is desired to optimize slightly off-resonant operation. Although careful design can overcome the coupling problem by the use of horn, lens, and perforated plates, the use of a semi-confocal interferometer that can be waveguide fed offers some advantages (waveguide feed has not been successful with flat plates). Calculations are presented here, however, only for the flat plate case since they are qualitatively applicable to the semi-confocal case and are much simpler. In the case of the flat plate interferometer, the quality factor is given by (Reference 36).

$$Q \simeq \frac{2\pi b/\lambda}{\delta_r + 0.207\left(\frac{b\lambda}{a^2}\right)^{1.4}}$$

where

a = plate (circular) radius

b = plate separation

λ = wavelength

δ_r = reflection losses.

Then the factor computed above, in the $P_{3\omega}$ expression, using $V = \pi a^2 b$, is

$$\frac{Q^3}{V^2} = \frac{8\pi b}{\lambda^3 a^4 \left[\delta_r + 0.207\left(\frac{b\lambda}{a^2}\right)^{1.4}\right]^3}.$$

Although δ_r and $\delta_d = 0.207\left(b\lambda/2\right)^{1.4}$ (the diffraction loss) are often of the same order magnitude in the millimeter range, to obtain a qualitative idea of the variation of Q^3/V^2, we neglect δ_r in comparison with δ_d. Thus

$$\frac{Q^3}{V^2} \approx \frac{8\pi}{(0.207)^3 \lambda^{7.2}} \frac{a^2}{b^{3.2}}.$$

At lower frequencies, however, the diffraction loss is less than δ_r; hence, under these conditions

$$\frac{Q^3}{V^2} \approx \frac{8\pi b}{\lambda^3 a^4 \delta_r}.$$

Although the manipulation of the Fresnel number $a^2/b\lambda$ can be accomplished to make the ratio of diffraction to reflection losses any desired quantity, it is better to keep the Fresnel number small (i.e.,) near one, to avoid moding problems. The quantity

$$\frac{Q^3}{V^2} \propto \frac{b}{a^4\left[\delta_r + 0.207\left(\frac{b\lambda}{a^2}\right)^{1.4}\right]^3}$$

has been plotted in Figure 1 for δ_r = 0.001, and 0.01, for a = 2, 3, 4, 5 cm and for $4 \leq b \leq 20$. (Comparisons should not be made between the two sets of curves for the different values of λ (λ = 0.8 cm and λ = 0.3 cm) since the scale has been compressed.) From the illustration, optimization of this quantity, important in the polarization at the third harmonic, can be carried out for the interferometer.

By the use of these formulas, one may optimize the resonator dimensions; however, the problem of independent tuning still remains. For this reason, consideration has been given to crossed interferometers (which were discussed in the last quarterly), but loss of both volume and filling factor result from this configuration. An alternative to this method is to use a frequency sensitive beam splitter as shown in Figure 2. In this way, two independently tuned interferometers can nevertheless have a large interaction volume for non-linear generation, and a large f_1 filling factor. (It is possible that semi-confocal plates may be used instead of the flat plates shown.)

The major problem in the design of this system is the beam splitter, which must be a good reflector for the low frequency and must transmit, with little attenuation, the high frequency. During the past quarter several designs have been evaluated and will be tried experimentally during the next period. Of the possible beam splitters considered, these receiving most attention are the polarizing slat grating type, the grid type, and the interference thin film type. The most successful of these will be the one with the lowest losses to the high frequency wave that must be transmitted.

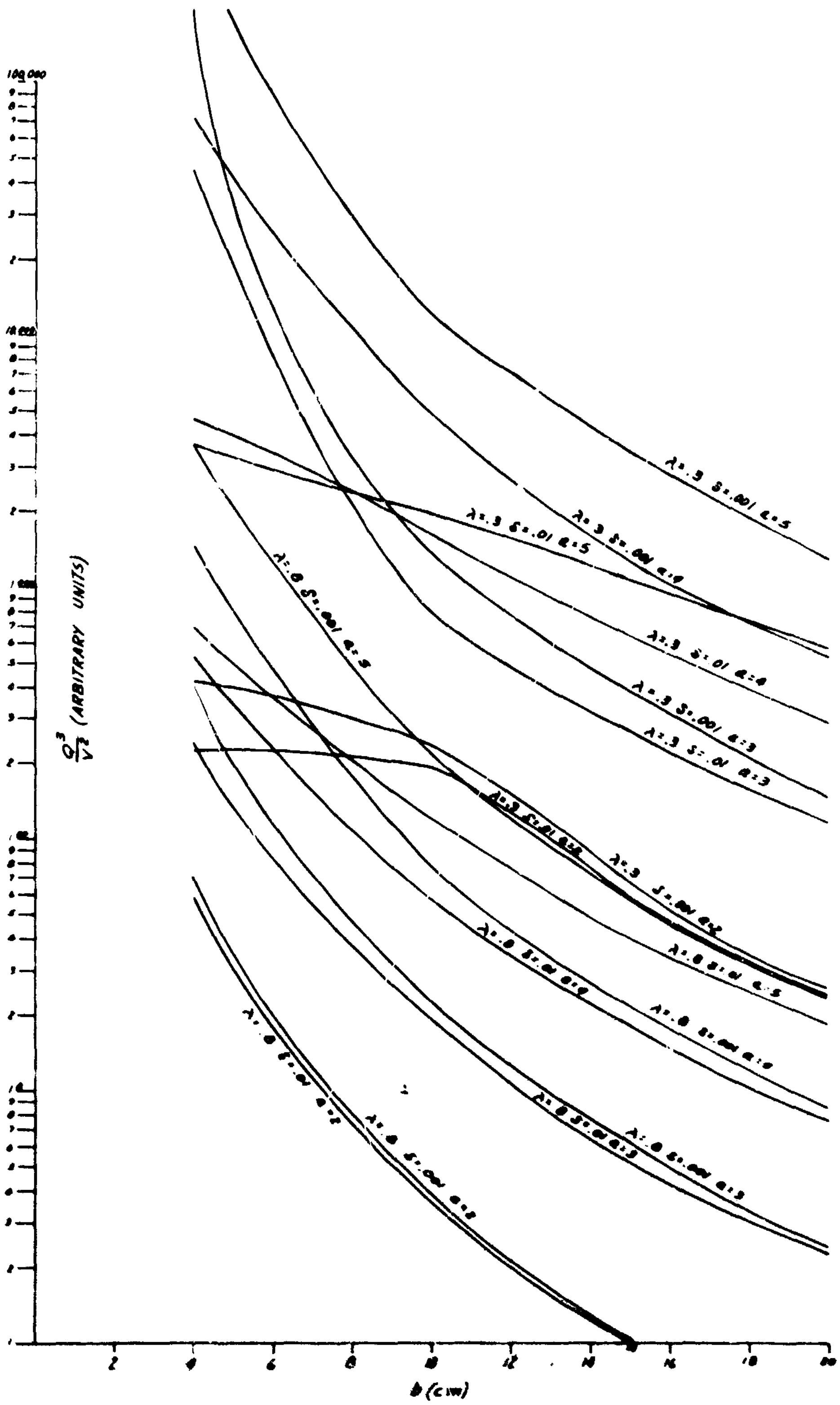

Figure 1. Interferometer Power Conversion Efficiency versus Resonator Geometry

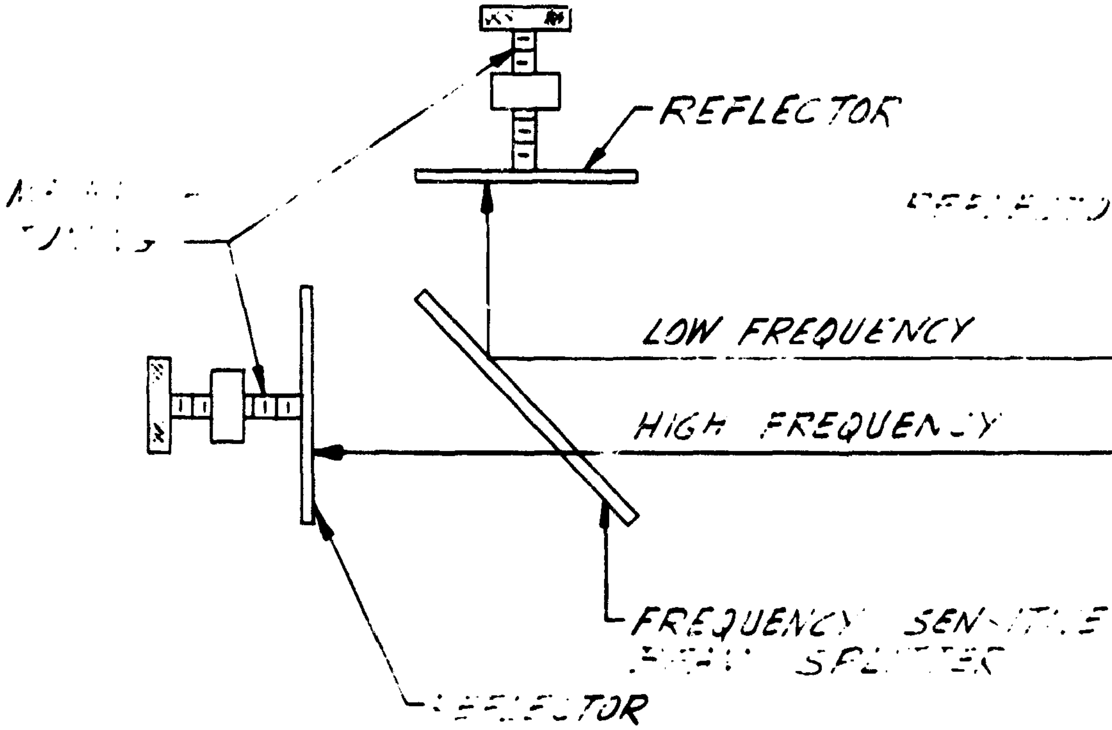

Figure 2. Beam Splitter Double Interferometer

The interference thin film type, an adaptation of the equivalent optical technique to millimeter wavelength, can be designed for high reflectance at the lower frequency. To obtain low loss at the higher frequency, it is necessary to obtain low loss dielectrics or use sets of thin mylar strips with alternating thicknesses. Calculations on this type will be reported in the next quarterly report.

The grid or grating types offer excellent possibilities, requiring, however, maximum skill in fabrication to obtain high reflectance at the low frequency and small attenuation of the third harmonic. The grid must be arranged as a set of equally spaced strips, at approximately the cut-off wavelength. To obtain sufficient attenuation, and hence reflection, the width of the strips must be a few wavelengths. The strips must be very thin, less than 0.001 inch, and of the greatest possible conductivity. A planned method of fabrication is to electroform nickel strips on stainless steel mandrels, to silver plate these and overlay with 50A of quartz to prevent deterioration of surface conductivity. An alternative method is to use metallized mylar strips. During the next quarter, a frequency-dependent beam splitter will be designed and construction begun.

C. GAS SELECTION

Selection of an appropriate gas for use in the totally resonant multiple quantum scheme presents several problems. For a four-level scheme used for third harmonic generation, the gas must possess non-vanishing dipole moments along two of the principal axes, and the energy levels must be equispaced. These properties can be found in asymmetric top molecules. As mentioned in the last quarterly report, nitrosyl fluoride was selected as a possible gas to be tried in a four-level third harmonic scheme to generate 120 GHz.

Conversations with representatives of Ozark Mahoning Company, the gas manufacturer, and R. L. Cook at Duke University who has performed microwave spectroscopy experiments with this gas, indicate handling problems. The Ozark representative stated that the gas can be used in contact with metallic objects if the objects are first pacified by the gas. This initial volume of gas used for pacification is then removed from the vacuum system and a fresh supply of gas used for the harmonic generation. Nitrosyl fluoride reacts on contact with ionization gages and mercury manometers, and the gas manufacturer does not recommend the use of these instruments in the vacuum system. To pump the gas out of the vacuum system, it is necessary to trap with liquid nitrogen since the gas is explosive on contact with pump oil. We are reworking a discarded vacuum system to investigate these gas handling problems.

Because of these handling problems with nitrosyl fluoride, we are considering other gases that may be used in the totally resonant system. Information is being accumulated on the following asymmetric gases to determine their possible application:

1 Nitrosyl chloride
2 Methylene chloride
3 Vinylene carbonate
4 Thionyl fluoride
5 Benzonitrile
6 Methylene fluoride
7 Vinyl cyanide
8 Hydrazoic acid
9 Ethylene sulfide
10 Difluorosilane
11 Isothyicyanic acid
12 Formaldehyde
13 Difluoroethylene.

We plan to continue the study of these gases and the experimentation required to devise proper gas handling techniques. Most of the corrosive gases are shipped in nickel or monel containers and information received from gas manufacturers recommend the use of nickel, monel, and inconel for vacuum system fabrication. With these considerations, we will investigate the use of nickel and nickel with gold plating. Another possible technique to prevent corrosion is the use of ultra thin quartz deposition on metallic surfaces. Martin-Orlando's Research Division has the facility to deposit quartz of as little as 50 angstroms thickness, allowing protection without interference with the microwave reflectivity.

All of these approaches will be tried with the ultimate goal of obtaining a suitable gas for third harmonic generation in the millimeter or submillimeter region.

No work was done during this quarter on the use of methyl cyanide because of the work on other gases. Calculation of the energy levels of methylene chloride was completed during the quarter, a complete tabulation of which is given in the Appendix.

III. DETAILS OF EXPERIMENTAL DESIGN AND CONSTRUCTION

The preliminary design and construction of experimental components is discussed in this chapter. These components consist of:

1 Flat plate interferometer plates

2 Semiconfocal interferometer plate

3 Low-pass filter for 35 GHz operation

4 Horn and lens design for 100 to 130 GHz operation.

The flat plate interferometers were designed according to the equations given in Zimmerer (Reference 37). In the construction of the parallel plate interferometer, the two critical parameters are the plate conductivity and flatness. Effort has been expended to maximize these parameters consistent with the use of the interferometer in a gaseous environment. Because of the long fabrication time and the imperfections of the holes in photoetched plates, the first flat interferometer plates were made by drilling the individual holes. Several thicknesses of aluminum foil from 0.005 to 0.030 thick were used. The foils were then stretched on aluminum rings to obtain a flat surface. Preliminary tests gave low Q values due to imperfect holes and wrinkling of the foil surface. As mentioned elsewhere in the report, many of the asymmetric top gases are highly corrosive and decompose readily.

The construction materials usually specified are nickel, monel, and inconel. For this reason, it was decided to construct the interferometer plates by electroforming nickel on a stainless steel mandrel. Several samples of various thicknesses were made. The quality of the holes is much better than those obtained by drilling or photoetching the holes. The nickel is much tougher than the equivalent thickness aluminum foil. Several nickel interferometers have been fabricated and mounted on aluminum rings. Since nickel has relatively low conductivity, it may be necessary to plate the nickel with a material of higher conductivity. Plating of the nickel foil is being investigated at the present time as well as other fabrication techniques.

The semiconfocal spacing of the interferometer described in the experimental part of this report is approximately 5 1/2 inches. Since the vacuum chamber can accommodate a greater interferometer length, a new curved plate assembly has been constructed, with semiconfocal length near 7 1/2 inches, to obtain a larger interaction volume. At the same time, several types of surface finishes will be tried on the curved mirror to maximize the Q value and maintain corrosion resistance. No experimental work has been done with this curved plate.

A low-pass filter was designed and constructed to be used with the magnetron. This filter will be waveguide-coupled to the magnetron to filter the third harmonic in the magnetron output. The filter was designed to cut off at 40 GHz. The filter consisted of several sections of different waveguide height to obtain the filter characteristic. When the magnetron power was applied, arcing occurred because of the reduced height of one of the sections in the direction of the electric field. To overcome this difficulty, the filter was filled with gaseous nitrogen and sealed with mica O-rings. When the filter was retested it operated satisfactorily. The response at the third harmonic was 30 db below the input signal.

A possible resonator for the totally resonant gas system is the parallel plate interferometer. A horn and lens system was fabricated to couple to this interferometer. The horns were fabricated in pieces, soldered together and the interior surfaces then highly polished. Further horn construction is planned by electroforming. It is possible to surface match the lenses which were machined from rexolite for a particular application, but it was not done in this preliminary design in order to expedite construction. The horn and lens system worked well, giving a transmission loss of about 3 db. For application in a gaseous medium, the lenses will be mounted directly to the horns to keep the absorbing gas out of the horns. This is important in the totally resonant system where the gas is highly absorbing. We are in the process of fabricating several of these horn-lens combinations.

IV. EXPERIMENTAL EFFORT DURING THIRD QUARTER

Experimental effort during the third quarter was concerned with system experiments using the semiconfocal resonator, and component evaluation for the parallel plate interferometer resonator. Work on the totally resonant system has been delayed because of the gas handling problems described elsewhere in this report.

During the second quarter of the contract, the several experiments to obtain third harmonic generation in methyl fluoride were unsuccessful. In these experiments, a semi-confocal interferometer was used as the resonator. A Microwave Associates Model 206 magnetron with a 0.25 μs pulsewidth supplied the power to the resonator. At the start of the third quarter it was decided to investigate thoroughly each of the following problems to optimize the experiment:

1 Coupling of magnetron power to cavity

2 Operation of magnetron at cavity frequency

3 Microwave window

4 Coupling third harmonic to cavity

5 Techniques to obtain simultaneous double resonance

6 Determination of field distribution in cavity.

Since the output power at the third harmonic frequency increased as the sixth power of the fundamental electric field, it is necessary to ensure optimum coupling of the input signal to the cavity. Also, large reflection at the input to the cavity results in standing waves, and the electric field in the input waveguide increases as the standing wave ratio becomes larger. This effect was probably responsible for the microwave window problem mentioned later in this report.

To obtain better coupling, the existing coupling iris was replaced by an open-end waveguide section. The distance between the end of the waveguide and the surface of the flat plate was made adjustable to permit the coupling to be tuned. The tuning range extended from a half-wavelength protruding into the cavity to a half-wavelength recessed into the flat plate. Unfortunately, the large opening required in the flat plate allowed other modes to be set up in the interferometer as observed on the oscilloscope. The impedance mismatch between the cavity and the waveguide was then measured and the iris hole size changed to correct for this mismatch. The experimental configuration is shown in Figure 3.

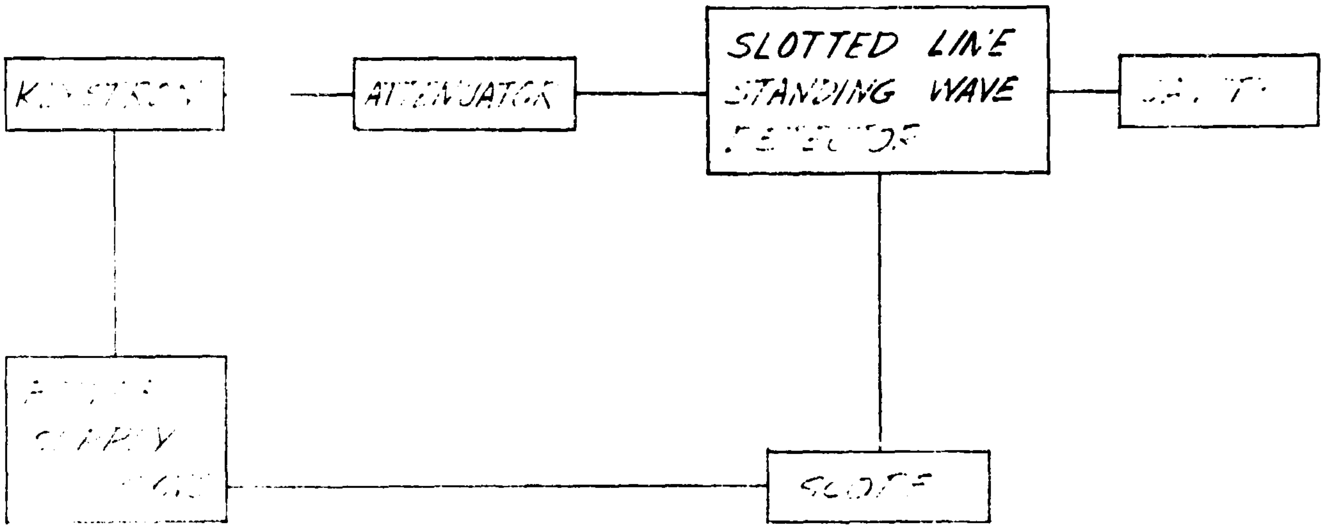

Figure 3. Cavity Coupling Setup

In this setup, a resonant mode is obtained on the oscilloscope display. The moving carriage of the standing wave detector is then moved until the resonant dip reverses polarity. When the cavity is matched to the waveguide, the tips of the resonant curve are at the same vertical position on the scope. As expected, it was found that the iris holes had to be increased in size to obtain better coupling. Since increasing the hole size will decrease the Q of the cavity, a tradeoff was necessary. The diameter of the iris was increased to 0.1 inch and the Q measured and found to be 29,000. The hole diameter was increased to 0.105 and then to 0.110 inch. With the hole diameter of 0.110 inch the Q-value had decreased to 16,000. Since only 2 db of mismatch was observed with this coupling, it was felt that any further enlargement of the hole size would cause an unjustifiably large decrease in the Q-value.

Since the cavity impedance changes rapidly near resonance, it is necessary to maintain the magnetron at the precise frequency of cavity resonance to obtain the highest possible electric field. Some experimental effort has been made to lock the cavity to the magnetron. A circuit configuration that might be used for this purpose is shown in Figure 4.

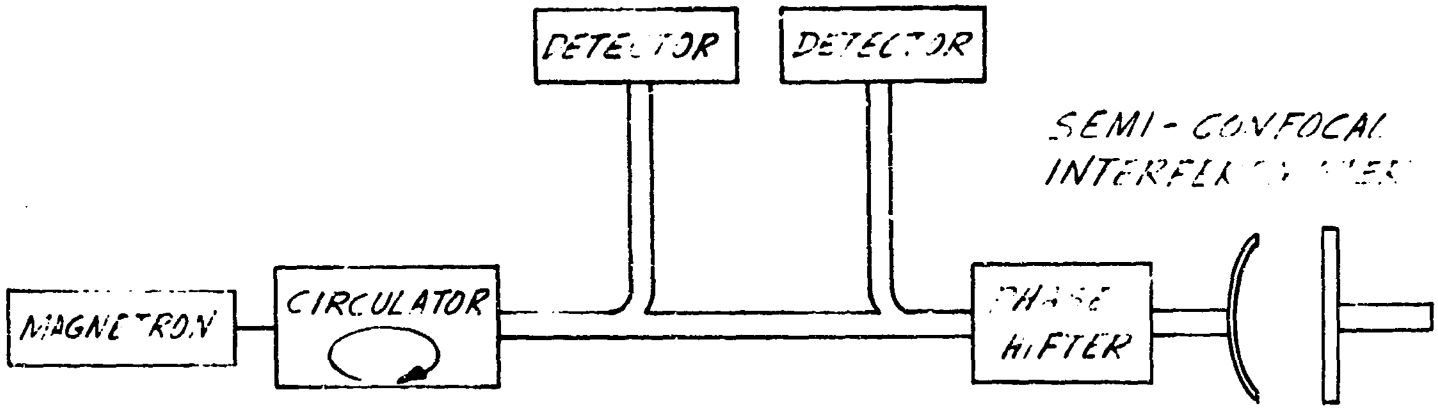

Figure 4. Magnetron - Cavity Lock Circuit

In this circuit, a low reverse isolation circulator reflects power back to the magnetron. A phase shifter is used to obtain the correct phase of the reflected signal. The reflector power is adjusted to a minimum, as noted by the detector used to monitor reflected power. This ensures the correct phase of the reflected signal to the magnetron to permit locking. Essentially, the cavity acts as part of the magnetron cavity to determine frequency. Several circulators have been tested to obtain acceptable reverse isolation and a selection has been made. No further work has been done on this problem.

The breakdown of microwave windows continues to be a problem. Various types of microwave windows have been tried, including mylar, teflon, glass, mica, and Microwave Associates Kovar glass windows. In the first experiment run to solve this problem, the microwave window was placed at a voltage minimum in the waveguide. The window did not break down with a vacuum in the cavity but did break down after a 20-minute interval with the gas in the cavity. Since the dielectric constant of the gas changes with pressure, it was not known whether the dielectric change or a chemical problem with the gas caused the problem. Conversation with various gas suppliers was not informative.

In a further experiment to determine whether there is a chemical reaction between methyl fluoride and the microwave window, gaseous nitrogen was pumped into the cavity and, after long application of magnetron power, the interferometer was disassembled and examined. The window was clear, indicating no reaction with gaseous nitrogen. Note that in other tests where the window broke down, black deposits occurred on the window and deposits occurred in the waveguide. The deposits in the waveguide were hard and had to be cut out. It is suspected that the gas reacts with the solder of the flange. In the next experiment a plexiglass window was used to replace the high frequency end of the jug. With this arrangement, it was possible to look into the interferometer with the magnetron power applied to determine whether ionization occurs. During this set of experiments it was found that electrical discharge occurred sporadically. No definite pattern could be observed. It was noted that when the vacuum obtained on initial pump down was not good enough, i.e., > 10 microns pressure, electrical discharge occurred when the gas was added. For this reason, it was decided to rebuild the window flange by inserting O-rings on both sides of the window to ensure a better vacuum. One test has been run with the new flange without ionization occurring.

The next problem investigated was the coupling of the third harmonic to the cavity. For this experiment, the third harmonic frequency was applied at the high frequency end of the cavity and the resonant signal detected at the flat plate output of the cavity in the transmission mode of operation (a circuit diagram is shown in Figure 5). The resonant signal was approximately 15 db down from the incident signal to the cavity, indicating good coupling into the cavity. Therefore, no further work was done in this area.

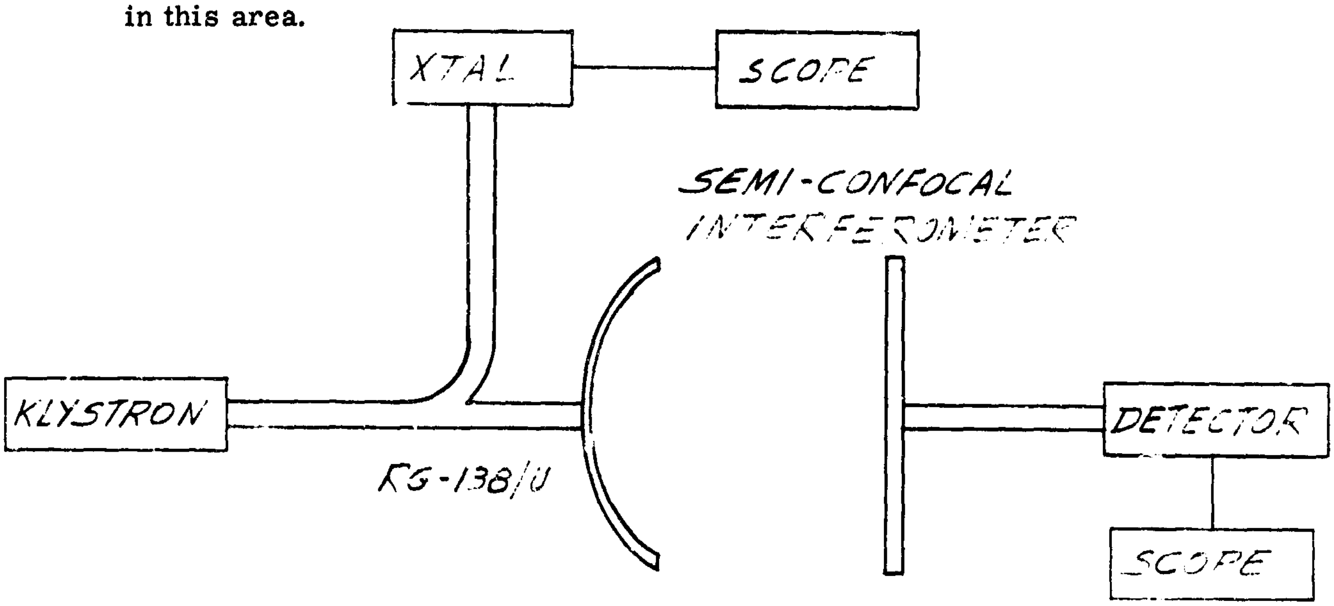

Figure 5. Test for Transmission of Third Harmonic in Interferometer Cavity

To obtain high electric field values in the cavity and effectively couple the third harmonic signal output from the cavity, it is necessary to obtain simultaneous resonance at ω and 3ω and, in general, to have independence of tuning for flexibility. Since the resonance equation for a semiconfocal interferometer shows that ω and 3ω resonances do not occur at the same spacing, it is necessary to introduce a perturbation to obtain the simultaneous resonance. For our semiconfocal interferometer it was found that a piece of tungsten wire of 0.005 inches in diameter placed about 1 inch from the flat plate surface gave the simultaneous double resonance (Figure 6). The Q-value at the third harmonic was not altered. Its measured value was 40,000. The Q-value of the fundamental was decreased to about 7000, a fractional decrease of about 2 1/2.

It is desirable for several reasons to be able to determine experimentally the field configurations in the cavity. The equations given in the literature are too complex and idealized to be useful. With the tungsten wire perturbation inserted into the cavity, it is necessary to determine whether the mode configuration changes and also the distortion of the electric field caused by the perturbation. A scheme for measuring the field distribution has been suggested by Zimmerer (Reference 38). The experimental setup consists of positioning a small piece of absorbing paper in the cavity field and determining the field intensity as a function of the reflection coefficient. The reflection coefficient is obtained by measuring the reflected cavity power with a bolometer and power bridge. The experimental setup is shown in Figure 7. To date, the variation of electric field transverse to the field direction at various axial positions has been obtained. Further tests to obtain the field distribution with the perturbing tungsten wire installed will be made to confirm preliminary tests.

The experimental effort on the totally resonant system consisted of component testing and evaluation. A horn and lens system was designed to operate in the frequency range between 100 GHz and 135 GHz. One application of this system is in the third harmonic generation in nitrosyl fluoride. To test these components, a parallel plate interferometer system was constructed that consisted of the horns-lens assembly and interferometer plates mounted on an optical bench. The initial fabrication of interferometer plates was not successful. The holes were drilled in an attempt to obtain a more uniform hole than had been obtained using photoetching techniques. Also, the photoetching process that had been used to fabricate other interferometer plates required about three weeks to obtain a finish foil. Unfortunately, the foil was too thin to allow clean drilling and the finished aluminum foil was not satisfactory. For these reasons, the parallel plate interferometer designed for 168 GHz operation was used. The system was aligned on the optical bench. The microwave signal was derived by frequency doubling from an OKI 55V10 klystron. The output was detected by use of a run-in RG 138 detector. The experimental setup is shown in Figure 8. The transmission loss with interferometer plates was 11 db while the transmission loss with horns and lens only was 3 db. The Q-value was approximately 8,000. It is expected that many more experiments on parallel

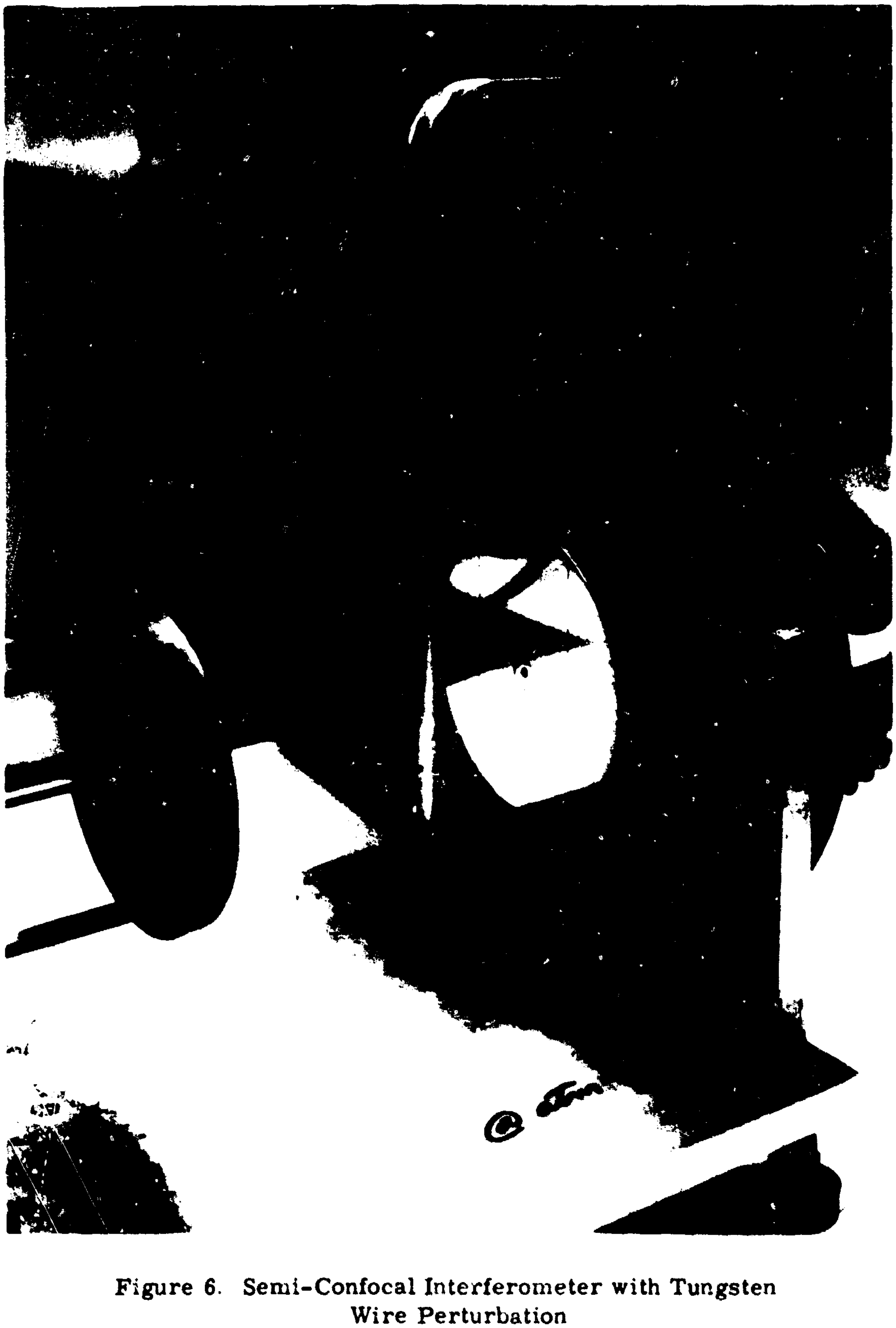

Figure 6. Semi-Confocal Interferometer with Tungsten Wire Perturbation

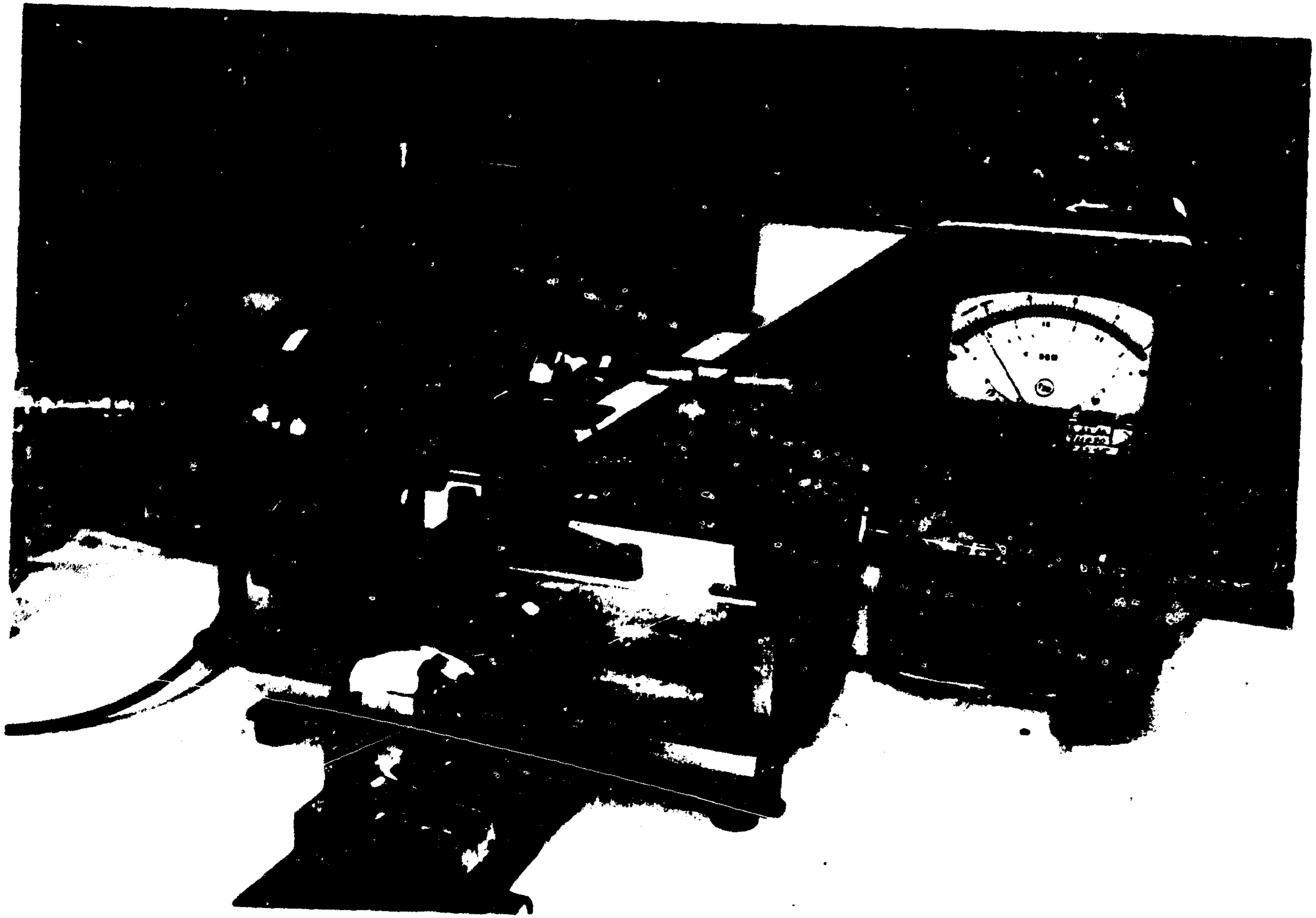

Figure 7. Measurement of Cavity Field Distribution

plate interferometers will be performed during the next quarter using the interferometer plates designed for multiple quantum experiments.

Figure 8. Setup for Measurement of Parallel Plate Interferometers

V. CONCLUSION

In analysis of the crossed interferometer system indicates a low filling factor for large intersection angles. The possible use of beam splitting techniques to solve this problem is promising. Further analysis and experimentation are required to obtain a feasible model. Since the semiconfocal interferometer has a large filling, its use in the partly resonant experiments is justified. The problem of field distortion in the semiconfocal interferometer, caused by the tungsten wire used to obtain simultaneous resonance, requires further investigation. Since the analytical expressions are complicated, experimental determination of the field distribution is used for this case. The gas handling problems with nitrosyl fluoride point to the use of another gas if a suitable one can be found.

VI. PROGRAM FOR NEXT QUARTER

Design and construction of resonant structures will continue. The design of a beam splitting interferometer will be completed and the construction of a beam splitter started. Selection of possible gases for the totally resonant scheme will be continued. An experimental setup will be made to check the gas handling problems of nitrosyl fluoride and other asymmetric top molecules. An attempt will be made to optimize the experiment for third harmonic generation in methyl fluoride. Experimentation on the totally resonant scheme will be continued. Non-linear quantum effects in solids will be studied at field strengths up to 50 kilogauss.

VII. KEY PERSONNEL

Manpower charges for the third quarter are as follows with Dr. V. E. Derr acting as task leader without charge to the contract:

G. W. Bechtold	387.8
R. A. Kempf	119.3
Engineering Aid	288.0
Model Shop	430.0
Presentations	31.0
F. Zlotshewer	64.0
L. Peirce	88.0

APPENDIX

Methylene Chloride Rigid Rotor Transition Frequencies*

Rotational Constants

A_o = 32,001.8 MHz

B_o = 3,320.4 MHz

C_o = 3,065.2 MHz

μ_b = 1.62

Selection rules:

ee ⟷ oo

eo ⟷ oe

Transition	Frequency (MHz)
$0_0 - 1_0$	35067.0
$1_{-1} - 1_1$	28936.6
$1_1 - 2_1$	99070.6
$1_0 - 2_2$	99327.4
$1_0 - 2_{-2}$	15911.8
$1_{-1} - 2_{-1}$	41197.4
$2_2 - 2_0$	86045.8
$2_2 - 3_2$	163201.2
$2_2 - 3_{-2}$	68038.5
$2_1 - 2_{-1}$	86809.8
$2_1 - 3_3$	163202.8
$2_1 - 3_{-1}$	66505.6

*Part of this table was presented in the preceding report. It has been completed and the entire table is given here.

Previous page was blank, therefore not filmed.

Transition	Frequency (MHz)
$2_0 - 2_{-2}$	29193.4
$2_0 - 3_0$	105201.0
$2_{-1} - 3_1$	105975.1
$2_{-1} - 3_{-3}$	9277.8
$2_{-2} - 3_2$	278440.6
$2_{-2} - 3_{-2}$	47200.8
$3_3 - 3_1$	144037.6
$3_3 - 3_{-3}$	259290.5
$3_2 - 3_0$	144046.0
$3_1 - 3_{-1}$	85670.9
$3_0 - 3_{-2}$	87193.6
$3_{-1} - 3_{-3}$	29582.0
$3_3 - 4_{-1}$	118504.9
$3_2 - 4_0$	118479.5
$3_2 - 4_{-4}$	233765.1
$3_3 - 4_3$	327205.6
$3_2 - 4_4$	227205.7
$3_1 - 4_1$	169583.4
$3_1 - 4_{-3}$	62173.5
$3_0 - 4_2$	169591.6
$3_0 - 4_{-2}$	59613.0
$3_{-1} - 4_3$	456914.2
$3_{-1} - 4_{-1}$	111203.5
$3_{-2} - 4_4$	458445.4
$3_{-2} - 4_0$	112760.2
$3_{-2} - 4_{-4}$	2525.3
$3_{-3} - 4_1$	284836.3
$3_{-3} - 4_{-3}$	53079.4

Transition	Frequency (MHz)
$4_{-4} - 4_{-2}$	30105.9
$4_{-4} - 4_{2}$	259310.9
$4_{-3} - 4_{-1}$	87706.1
$4_{-3} - 4_{3}$	433416.7
$4_{0} - 4_{2}$	144025.3
$4_{-2} - 4_{0}$	85179.5
$4_{-2} - 4_{0}$	85179.5
$4_{-2} - 4_{4}$	430864.7
$4_{1} - 4_{3}$	201659.8
$4_{-1} - 4_{1}$	144050.7
$4_{2} - 4_{4}$	201659.8
$4_{-4} - 5_{-4}$	58836.6
$4_{-4} - 5_{0}$	291244.6
$4_{-4} - 5_{4}$	752180.0
$4_{-3} - 5_{-5}$	4340.1
$4_{-3} - 5_{-1}$	119689.6
$4_{-3} - 5_{3}$	465348.5
$4_{-2} - 5_{-2}$	117078.3
$4_{-2} - 5_{2}$	462796.5
$4_{-1} - 5_{1}$	175984.7
$4_{-1} - 5_{5}$	636919.9
$4_{0} - 5_{0}$	175959.0
$4_{0} - 5_{4}$	636894.4
$4_{1} - 5_{-5}$	227416.7
$4_{1} - 5_{-1}$	112067.2
$4_{1} - 5_{3}$	233591.6
$4_{2} - 5_{-2}$	112126.5
$4_{2} - 5_{2}$	233591.6

Transition	Frequency (MHz)
$4_3 - 5_{-3}$	398306.2
$4_3 - 5_1$	169725.9
$4_3 - 5_5$	291209.2
$4_4 - 5_{-4}$	402134.0
$4_4 - 5_0$	169726.1
$4_4 - 5_4$	291209.2
$5_{-5} - 5_{-3}$	30770.3
$5_{-5} - 5_1$	259350.6
$5_{-5} - 5_5$	720285.9
$5_{-4} - 5_{-2}$	88347.6
$5_{-4} - 5_2$	434065.8
$5_{-3} - 5_{-1}$	84579.1
$5_2 - 5_4$	259277.5
$5_{-3} - 5_3$	430238.0
$5_3 - 5_5$	259277.5
$5_{-2} - 5_0$	144060.2
$5_{-2} - 5_4$	604995.6
$5_{-1} - 5_1$	144001.1
$5_{-1} - 5_5$	604936.3
$5_0 - 5_2$	201657.9
$5_1 - 5_3$	201657.7
$5_{-5} - 6_{-5}$	64477.1
$5_{-5} - 6_{-1}$	297673.2
$5_{-5} - 6_3$	758603.7
$5_{-4} - 6_{-6}$	11311.7
$5_{-4} - 6_{-2}$	12677[illegible].2
$5_{-4} - 6_2$	47238[illegible].2
$5_{-3} - 6_{-3}$	122825.8
$5_{-3} - 6_1$	468557.4

Transition	Frequency (MHz)
$5_{-3} - 6_{5}$	1044728.4
$5_{-2} - 6_{-4}$	45454.4
$5_{-2} - 6_{0}$	182383.5
$5_{-2} - 6_{4}$	643313.5
$5_{-1} - 6_{-5}$	50872.3
$5_{-1} - 6_{-1}$	182323.6
$5_{-1} - 6_{3}$	643254.2
$5_{0} - 6_{-6}$	221096.1
$5_{0} - 6_{-2}$	105635.7
$5_{0} - 6_{2}$	239977.2
$5_{0} - 6_{6}$	816148.2
$5_{1} - 6_{-3}$	105754.4
$5_{1} - 6_{1}$	239977.0
$5_{1} - 6_{5}$	816148.0
$5_{2} - 6_{-4}$	391172.6
$5_{2} - 6_{0}$	163334.5
$5_{2} - 6_{4}$	297595.3
$5_{3} - 6_{-5}$	396531.2
$5_{3} - 6_{-1}$	163335.1
$5_{3} - 6_{3}$	297595.3
$5_{4} - 6_{-2}$	566571.1
$5_{4} - 6_{2}$	220598.1
$5_{4} - 6_{6}$	355212.8
$5_{5} - 6_{-3}$	566689.7
$5_{5} - 6_{1}$	220958.1
$5_{5} - 6_{5}$	355212.8

REFERENCES

1. M. Goppert-Mayer, Ann Physik 9, 273 (1931)

2. A. Javan, Bull Amer Phys Soc Ser II, 3, 213 (1958)

3. A. Javan, "Transitions a Plusieurs Quanta et Amplification Maser Dans les Systemes a Deux Niveaux," Jour de Phys et Rad 19, 806 (1958)

4. A. Kastler, "Transitions de Radiofrequence a Deux Quanta et Effet Raman," Journ de Phys et Rad 15, 323 (1954)

5. J. Weber, Rev Mod Phys 31, 681 (1959)

6. G. Eckhardt, R. W. Hellworth, F. J. McClung, S. E. Schwarz and D. Weiner, "Stimulated Raman Scattering from Organic Liquids," Phys Rev Letters 9, 455 (1962)

7. E. J. Woodbury and W. K. Ng, "Ruby Laser Operation in the Near IR," Proc IRE 50, 2367 (1962)

8. H. J. Zeiger and P. E. Taunenwald, "The Raman Maser," pp 1589-1596, Quantum Electronics III

9. V. Hughes and L. Grabner, Phys Rev 79, 314 and 829 (1950)

10. L. Grabner and V. Hughes, Phys Rev 79, 819 (1950) and 82, 561 (1951)

11. P. Kusch, Phys Rev 93, 1022 (1954)

12. H. Salwen, Phys Rev 99, 1274 (1955)

13. N. F. Ramsey, Phys Rev 100, 1191 (1955)

14. J. Brossel, B. Cagnac, A. Kastler, Compst Rend Acad Sci Paris, 237

15. C. Besset, J. Horowitz, A. Messiah and J. Winter, Journ Phys Radium 15, 251 (1954)

16. M. N. Hack, Phys Rev 104, 84 (1956)

17. P. Kusch, Phys Rev 101, 627 (1956)

18. A. Kastler, "Different Types of Multiple Quantum Transitions," Proceedings of the Ann Arbor Conference on Optical Pumping

19. A. Kastler, "Les Methodes de la Resonance Hertzienne," Nuovo Cimento Supplement to Vol VI, pp 1148-1167 (1957)

20. C. Besset, J. Horowitz, A. Messiah and J. Winter, "Sur le Probleme des Resonances Entre Plusieurs Niveaux Dan un Ensembles D'atomes Orientes," Journ de Phys et Rad 13, 251 (1954)

21. A. Kastler, "Optical Methods of Atomic Orientation and of Magnetic Resonance," Journ Opt Soc Amer 47, 460 (1956)

22. I. D. Abella, "Optical Double-Photon Absorption in Cesium Vapor," Phys Rev Letters 9, 453 (1962)

23. J. Barrat, J. Brossel and A. Kastler, Compt Rend 239, 1196 (1954)

24. J. Margerie and J. Brossel, Compt Rend 241, 373 (1955)

25. J. M. Winter, Compt Rend 241, 375, 600 (1955)

26. J. Brassell, J. Margerie and J. M. Winter, Compt Rend 241, 556 (1955)

27. J. R. Fontana, R. H. Pantell, R. G. Smith, "Harmonic generation by Means of Multiple Quantum Transitions," Advances in Quantum Electronics, J. R. Singer, Ed, Columbia University Press, New York, New York, 1961

28. R. G. Smith, PhD dissertation, Stanford University, July 1963

29. J. R. Fontana, R. H. Pantell, R. G. Smith, "Harmonic Generation Using the Ammonia Inversion Transition," Proc IEEE 50, 469-470 (1962)

30. C. M. Kellington, "Resonant Harmonic Generation in Ruby," Phys Rev Letters 9, 57 (1962)

31. R. H. Pantell and R. G. Smith, "Multiple Quantum Effects at Millimeter Wavelengths," IEEE Transactions on Microwave Theory and Techniques MTT-11, 317 (1963)

32. H. G. Andresen "Generation of Millimeter Waves by Multiple Quantum Transitions," paper 6.5, The Millimeter and Submillimeter Conference, Orlando, Florida, Jan 7-10, 1963

33. H. G. Andresen, H. Welling, and K. D. Miller, "Resonant Frequency Mixing Effects in Distributed Media," Proceedings of the Third International Congress on Quantum Electronics, pp 1507-1602

34. D. P. Akitt and P. D. Coleman, "Harmonic Generation in HCN by Multiple Quantum Conversion," Journ Appl Phys, Vol 36, No. 6, June 1965

35. D. J. Scalapino, A. Vasseliadis and R. N. Wilson, "Multiple Quantum Frequency Conversion in Extended Interaction Structures," Paper III-4 PGMTT Meeting June 1964

36. Fox and Li, "Resonant Modes in a Maser Interferometer," The Bell System Technical Journal, March 1961

37. R. W. Zimmerer, "Millimeter Wavelength Resonant Structures," IEEE Transactions on Microwave Theory and Techniques, March 1963

38. R. W. Zimmerer, "Spherical Mirror Fabry-Perot Resonators," IEEE Transactions on Microwave Theory and Techniques, September 1963

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Martin-Marietta Corporation Orlando, Florida	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

QUANTUM MULTIPLIERS AND MIXERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Third Quarterly Report - 1 November 1965 - 31 January 1966

5. AUTHOR(S) (Last name, first name, initial)

Derr, V. E.
Bechtold, G. W.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1966		

8a. CONTRACT OR GRANT NO. DA28-043 AMC-01320 (E) b. PROJECT NO. IP6-22001-A-05803 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) OR 8101 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ECOM-01320-3

10. AVAILABILITY/LIMITATION NOTICES This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Commanding General, U.S. Army Electronics Command Fort Monmouth, New Jersey, AMSEL-KL-SM.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Army Electronics Command Fort Monmouth, New Jersey AMSEL-KL-SM

13. ABSTRACT Various resonant structures that may be used in harmonic generation and frequency mixing experiments are discussed. The important parameters considered are simultaneous double resonance, filling factor, and resonator losses. The discussion compares the relative merits of various resonators. The semi-confocal interferometer has been used in partly resonant gas experiments using methyl fluoride. Crossed parallel plate interferometers have been designed for use in third harmonic generation in nitrosyl fluoride. Problems related to the use of the interferometers in multiple quantum experiments are discussed. Beam splitting techniques to improve the filling factor are discussed. The use of asymmetric top molecules in multiple quantum experiments is complicated by the corrosive properties of these gases. This problem is reviewed. The experimental phase of the work was concerned with experiments to optimize the resonator structure for the partly resonant experiments and evaluation of components to be used in the totally resonant work. This progress is discussed. The energy levels of methylene chloride have been completed and are given in the appendix. Work on multiple quantum effects in solids was not continued in order to allow for revision of test equipment to incorporate a superconducting magnet in the test setup. Work on multiple quantum effects in solids will continue in the next quarter.

DD FORM 1 JAN 64 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Harmonic Generation Frequency Mixing Resonant Structures Interferometer Multiple Quantum Effects						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

OR 8101

Martin-Marietta Corporation
QUANTUM MULTIPLIERS AND MIXERS
April 1966
(Contract No. DA-28-043-AMC-01320(E))
49 p. UNCLASSIFIED REPORT

Various resonant structures used in harmonic generation and frequency mixing experiments are discussed. Parameters considered are simultaneous double resonance, filling factor, and resonator losses. The semiconfocal interferometer has been used in partly resonant gas experiments using methyl fluoride. Beam splitting techniques to improve the filling factor are discussed. The energy levels of methylene chloride have been completed and are given in the appendix.

UNCLASSIFIED

1. Multipliers - Quantum Electronics
2. Mixers - Frequency
3. Harmonic Generation
4. Resonance

I. DA-28-043-AMC-01320(E)
II. Derr, V. E.
III. Bechtold, G. W.

OR 8101

Martin-Marietta Corporation
QUANTUM MULTIPLIERS AND MIXERS
April 1966
(Contract No. DA-28-043-AMC-01320(E))
49 p. UNCLASSIFIED REPORT

Various resonant structures used in harmonic generation and frequency mixing experiments are discussed. Parameters considered are simultaneous double resonance, filling factor, and resonator losses. The semiconfocal interferometer has been used in partly resonant gas experiments using methyl fluoride. Beam splitting techniques to improve the filling factor are discussed. The energy levels of methylene chloride have been completed and are given in the appendix.

UNCLASSIFIED

1. Multipliers - Quantum Electronics
2. Mixers - Frequency
3. Harmonic Generation
4. Resonance

I. DA-28-043-AMC-01320(E)
II. Derr, V. E.
III. Bechtold, G. W.

OR 8101

Martin-Marietta Corporation
QUANTUM MULTIPLIERS AND MIXERS
April 1966
(Contract No. DA-28-043-AMC-01320(E))
49 p. UNCLASSIFIED REPORT

Various resonant structures used in harmonic generation and frequency mixing experiments are discussed. Parameters considered are simultaneous double resonance, filling factor, and resonator losses. The semiconfocal interferometer has been used in partly resonant gas experiments using methyl fluoride. Beam splitting techniques to improve the filling factor are discussed. The energy levels of methylene chloride have been completed and are given in the appendix.

UNCLASSIFIED

1. Multipliers - Quantum Electronics
2. Mixers - Frequency
3. Harmonic Generation
4. Resonance

I. DA-28-043-AMC-01320(E)
II. Derr, V. E.
III. Bechtold, G. W.

OR 8101

Martin-Marietta Corporation
QUANTUM MULTIPLIERS AND MIXERS
April 1966
(Contract No. DA-28-043-AMC-01320(E))
49 p. UNCLASSIFIED REPORT

Various resonant structures used in harmonic generation and frequency mixing experiments are discussed. Parameters considered are simultaneous double resonance, filling factor, and resonator losses. The semiconfocal interferometer has been used in partly resonant gas experiments using methyl fluoride. Beam splitting techniques to improve the filling factor are discussed. The energy levels of methylene chloride have been completed and are given in the appendix.

UNCLASSIFIED

1. Multipliers - Quantum Electronics
2. Mixers - Frequency
3. Harmonic Generation
4. Resonance

I. DA-28-043-AMC-01320(E)
II. Derr, V. E.
III. Bechtold, G. W.